

# *Design and Development of a 100 MVA HTS Generator*

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## **Los Alamos National Laboratory**

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FY2004 Project Funding: \$430 k (LANL/DOE)  
\$430 k (GE in-kind)

2004 DOE Annual Peer Review  
Washington, DC July 27-29, 2004



# Outline

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- Results of FY 2004
  - Long Term Vacuum Maintenance
  - Heat Pipe Cooling
  - Closed Loop, Passively Pumped Cooling
  - AC Loss/Over-current Fault
- FY 2004 Performance
- FY 2005 Plans
- Research Integration



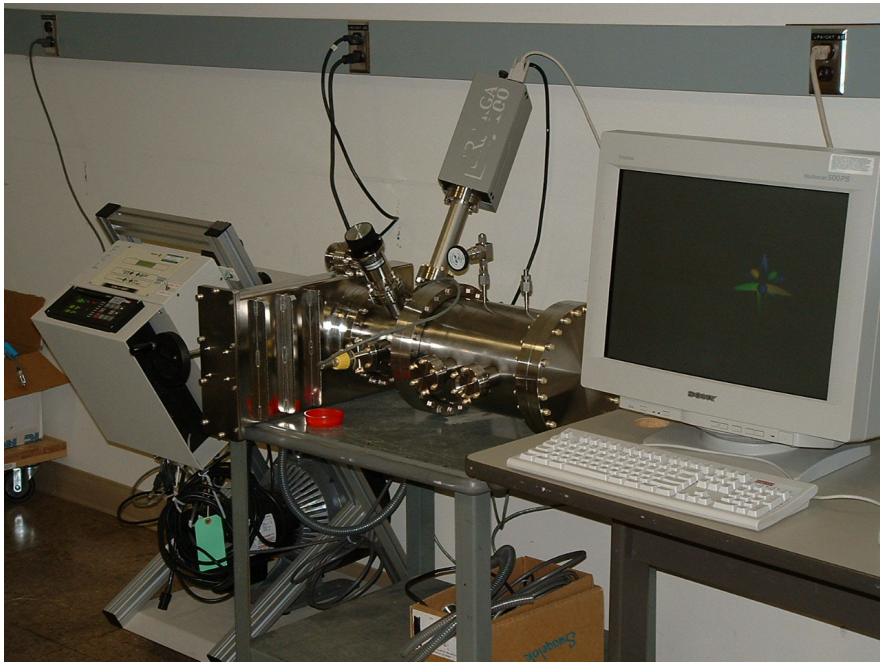
# Long Term Vacuum Maintenance

*reduce heat loads ■ reduce refrigeration \$ ■ increase efficiency*

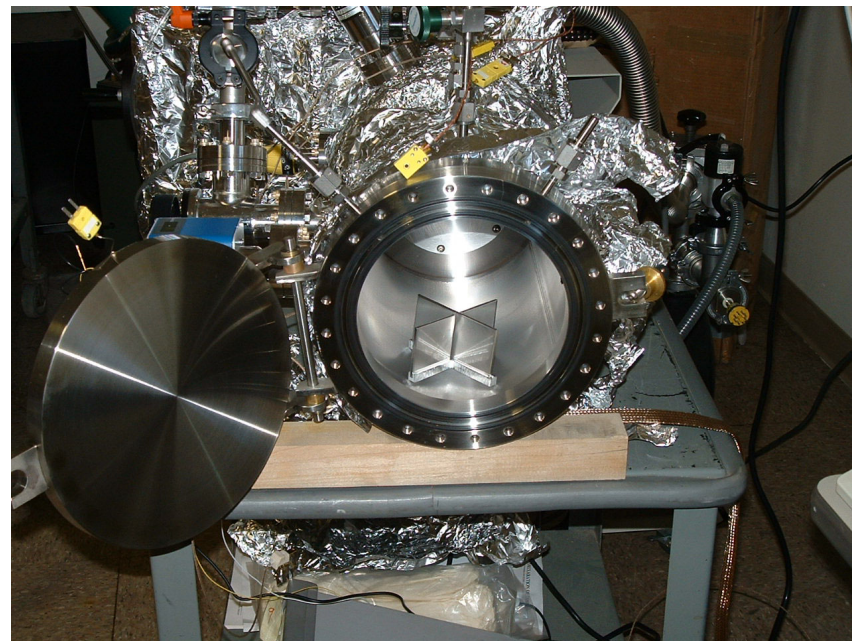
- Outgassing properties of materials
  - gas species
  - quantity of each species
- Getter material identification and characterization  
*(LANL ID'd, supplied, discussed; GE using vendor info)*
- Vacuum maintenance prescription: linking outgassing and amount/type of gettering mat'l  
*(LANL article published in Adv. Cryo. Eng., Vol 49)*



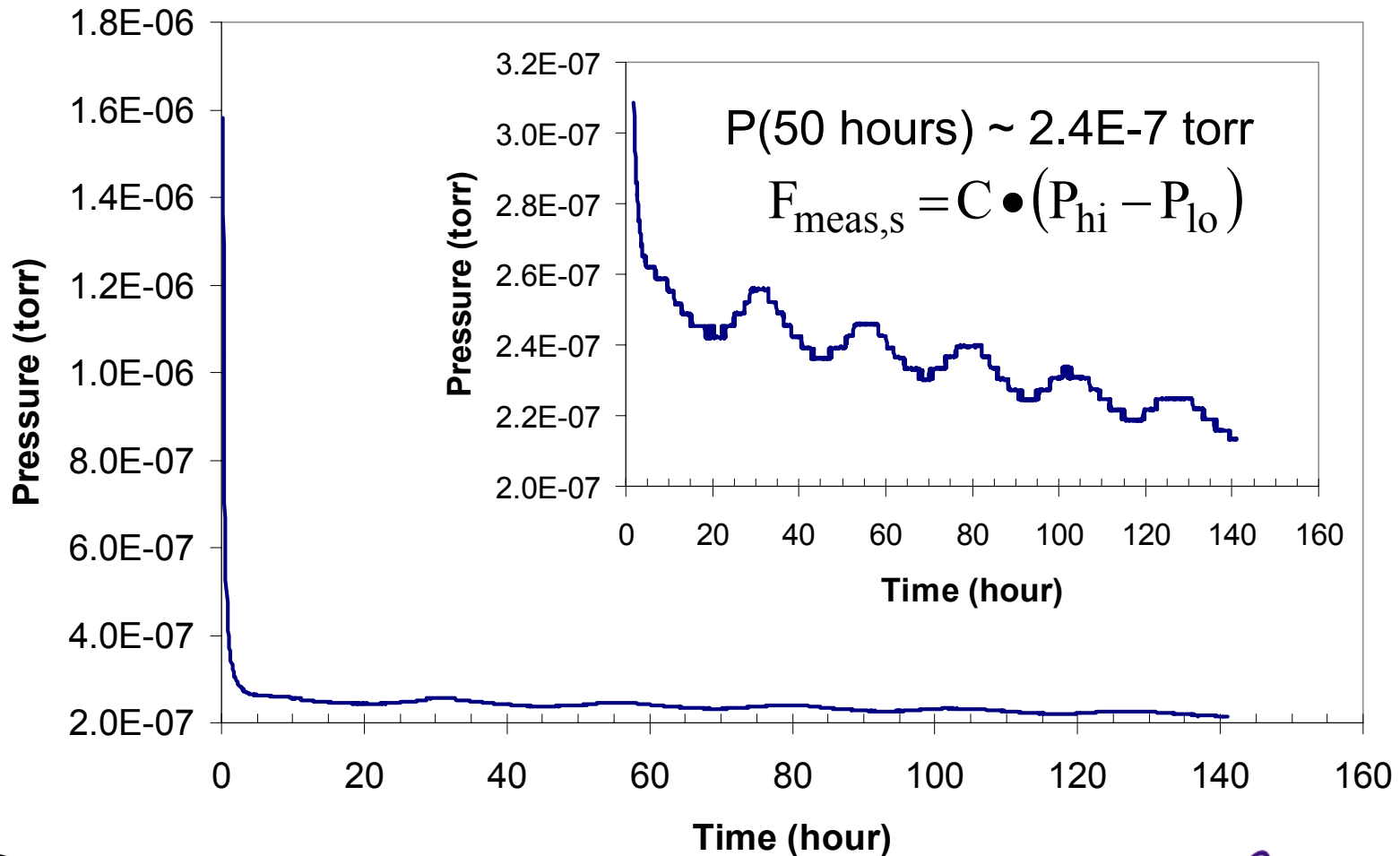
# Outgassing Measurements - 1



pump chamber      orifice      sample chamber



# Outgassing Measurements - 2



# ***Outgassing Measurements - 3***

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## Status

- Over 100 outgassing experiments performed  
each requires 50 hours or more
- 12 different materials measured
- Determined uncertainty & repeatability
- Determined effect of orifice size
- Assessing low temperature bake-out of samples
- Assessing impact of 'non-virgin' samples
- Coordinating results with emissivity degradation



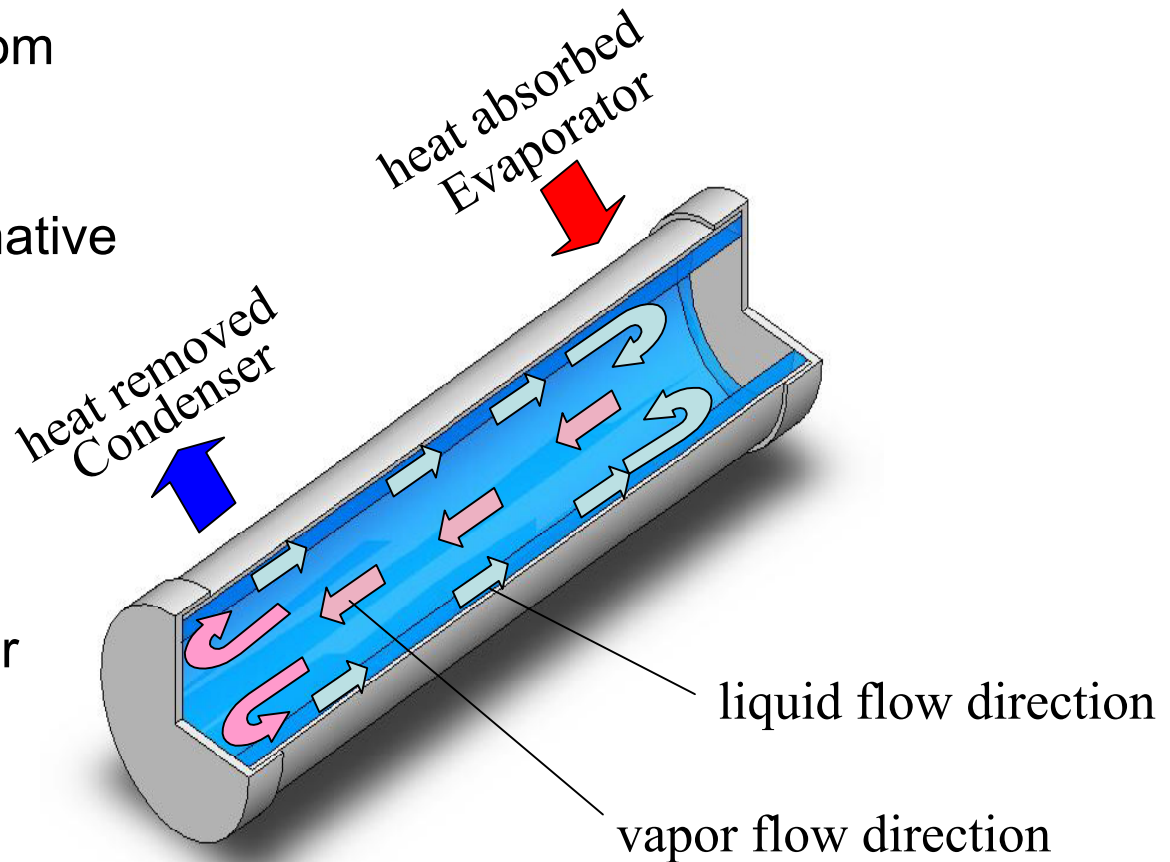
# Heat Pipe Cooling - 1

*smaller  $\Delta T$  load/cooler ▮ reduce refrigeration \$ ▮ increase efficiency*

Ultimately transfer heat from  
load to cryocoolers

Higher performance alternative  
to GE baseline

Orders-of-magnitude  
more efficient heat transfer  
than pure conduction

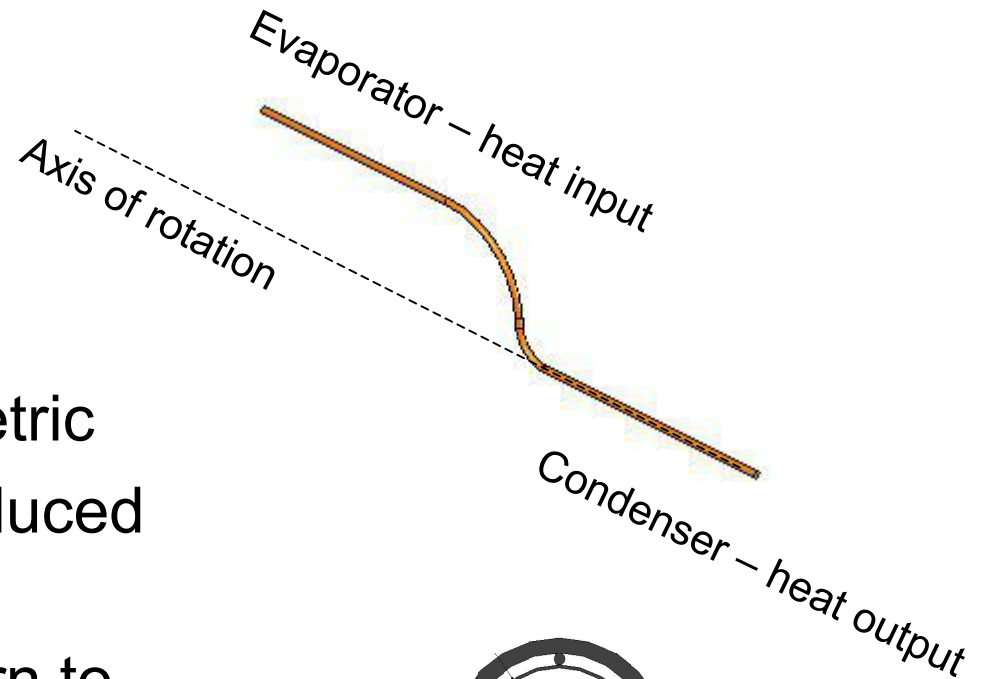




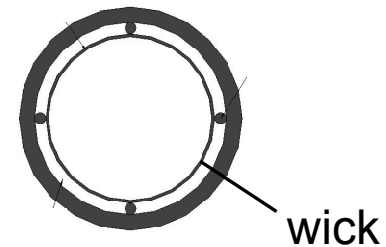
# Heat Pipe Cooling - 2

Heat pipe thermal model  
(*unique high-g environment*)

- very detailed axi-symmetric
- incorporates rotation induced body forces
- indicates vapor will return to condenser against g-forces



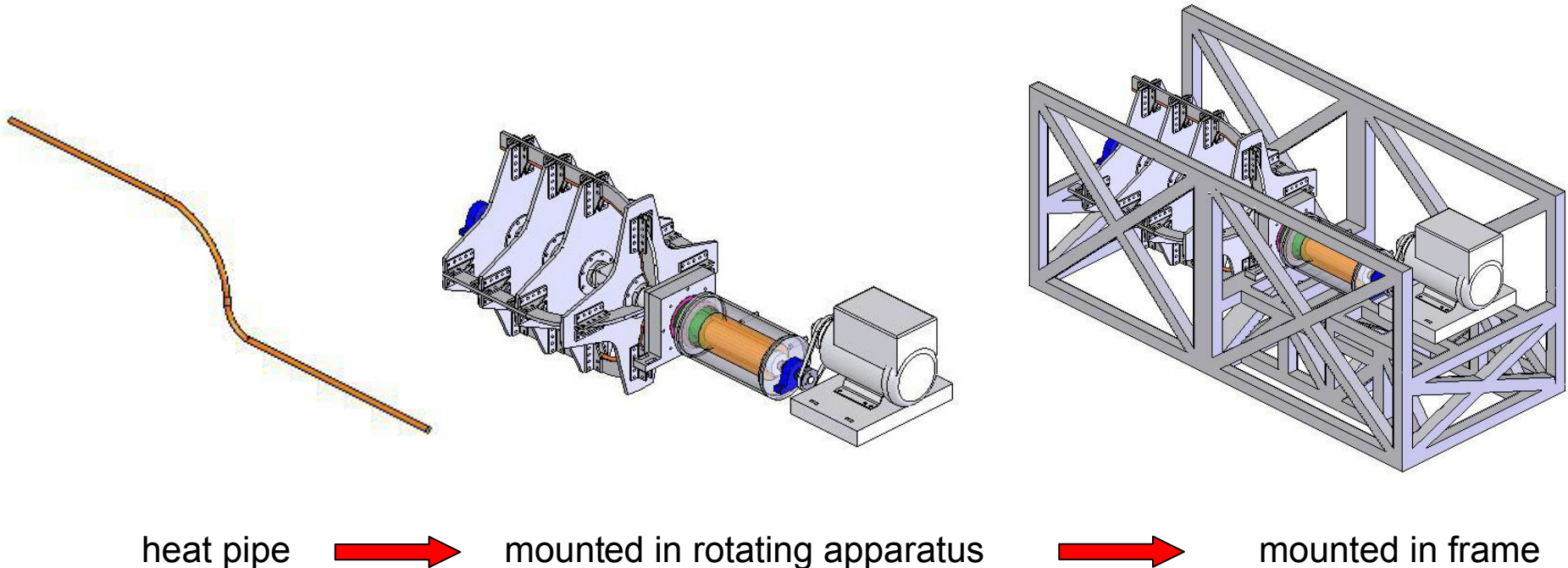
Cross-section  
view





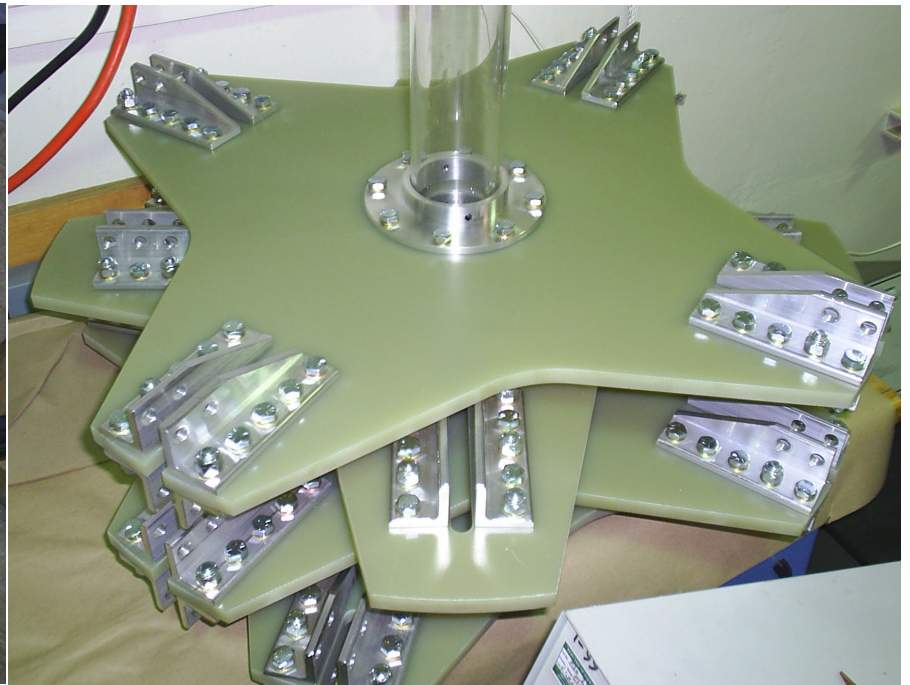
# *Heat Pipe Cooling - 3*

Room-temperature apparatus to verify model and performance



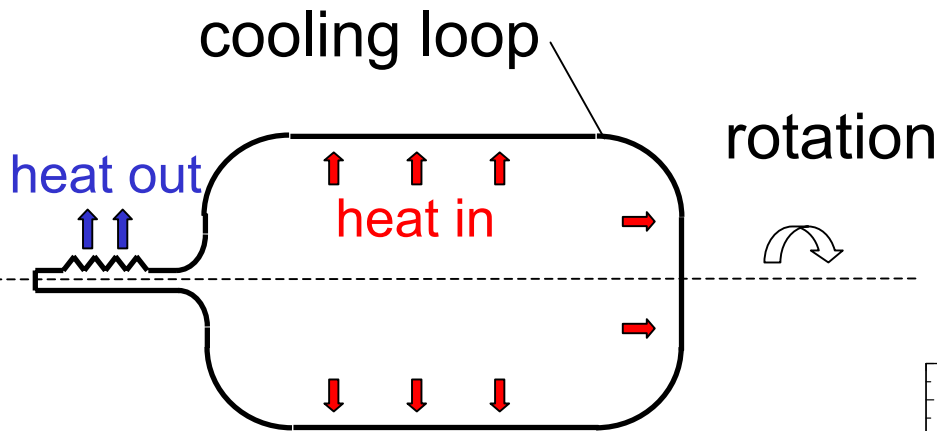
# Heat Pipe Cooling - 4

- All components are at LANL being assembled
- Heat pipe is undergoing stationary bench tests (developing wick assembly procedures)



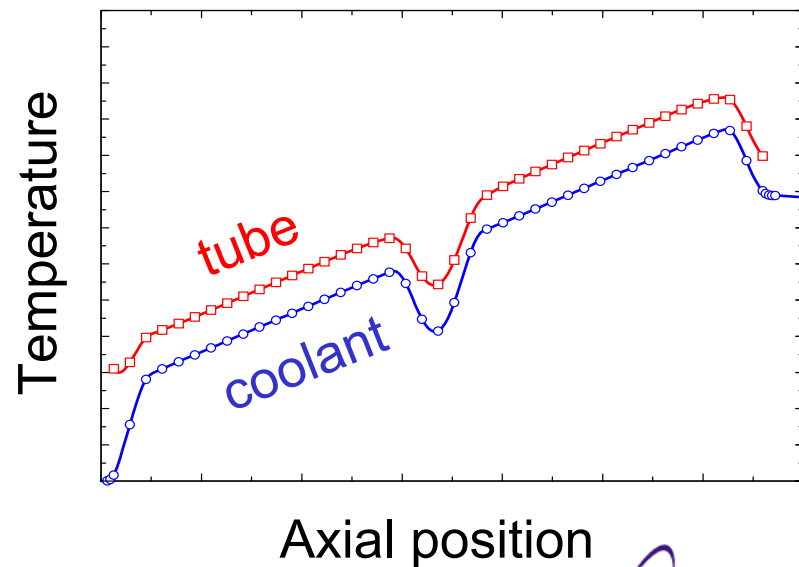
# Closed Loop Passively Pumped Cooling

*smaller  $\Delta T$  load/cooler  $\Rightarrow$  reduce refrigeration \$  $\Rightarrow$  increase efficiency*



*GE Proposed  
LANL analyzed*

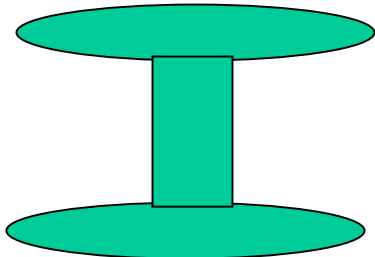
*Simple but requires rotation*



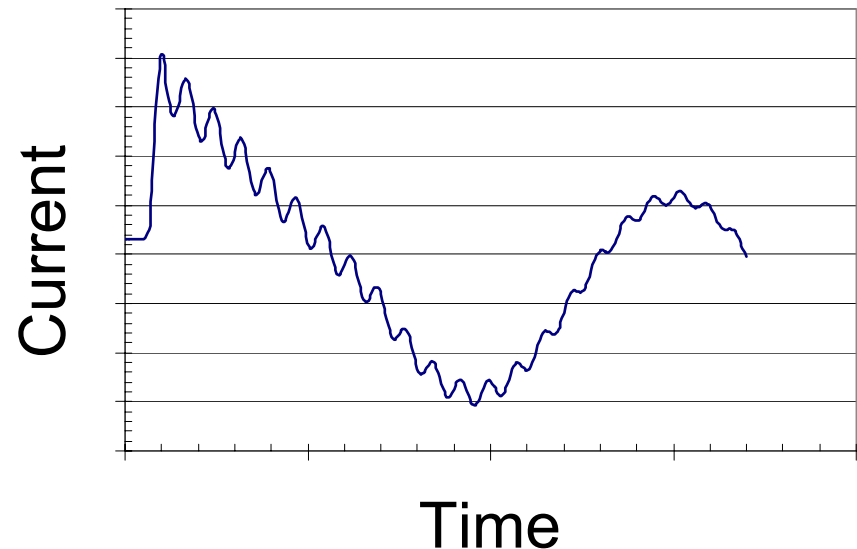
# AC Loss – Over-current Fault

*protect HTS coil during fault condition  
thermal & voltage issues; impact on cooling; recovery time*

Picture of apparatus



fault current profile



# ***FY 2004 Performance - 1***

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- LANL is responding to changes in CRADA scope:

- ☐ **Outgassing material characterization;**

*new materials being received; over 100 different measurements performed; two reports sent, third in process, (increased scope at GE request).*

- ☒ **Getter material evaluation;**

*GE/LANL discussions; vendor discussions; LANL supplied material; no experiments needed, using vendor supplied data.*

- ☒ **Vacuum maintenance prescription;**

*generic description presented in Adv. Cryo. Eng. Vol 49, 2004.*





# ***FY 2004 Performance - 2***

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## **Rotating heat pipe assessment;**

- ☒ *Assessment and thermal model completed, presented and published 2004 ASME Heat Transfer/Fluids Conference; patent applied for*

- ☐ *heat pipe and rotating apparatus being assembled (increased scope at GE request)*

***not listed last year in Plans***

- ☒ **Closed loop, passively pumped cooling assessment;** *developed thermal model; assessed impact on rotating apparatus configuration; three reports; (increased scope at GE request)*

- ☐ **AC loss/Over-current measurement;** *sensors installed; coil integrated with cryocooler; repairing sensor connections, LANL has fault-current profile*

- ☐ **Assess 2nd generation HTS conductor impact;** *lower priority task for GE; LANL obtained spec sheet*



# ***FY 2005 Plans***

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- Specific CRADA deliverables (reports) will be met:
  - ***Extend CRADA with GE to cover new scope.***
  - ***Outgassing material characterization*** – bake-out, emissivity coordination, new samples; submit reports as needed.
  - ***Rotating heat pipe experiment*** - apparatus assembled, data acquired, compare to model, write report.
  - ***Closed loop, passively pumped cooling experiment*** – modify rotating apparatus; fabricate/integrate loop; take measurements, compare to model, write report
  - ***AC loss/Over-current*** – repair sensor connections, take measurements, compare to model predictions, write report
  - ***2nd generation HTS conductor impact*** – assess impact, write report.





# *Research Integration*

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- Frequent interactions with GE, review direction, efforts, and results
- Exchange of samples, materials, sensors, software models with GE
- Interactions with LANL experts; materials, data acquisition
- Discussions with ORNL correlating emissivity with condensates of residual gases
- Paper on outgassing presented at CEC, published in Advances in Cryogenic Engineering; paper on rotating heat pipe presented at 2004 ASME Heat Transfer/Fluids Engineering Summer Conference, published in proceedings of same; patent applied for
- Interactions with Prof. Razani of University of New Mexico on heat pipes (PhD thesis advisor of LANL student Todd Jankowski)



# Summary

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- Long Term Vacuum Maintenance:
  - completed getter material and long term maintenance prescription
  - measuring outgassing properties as needed
- Rotating Heat Pipe and Closed-Loop Passively Pumped Cooling
  - assessments and modeling completed
  - apparatus being assembled
- AC Loss/Over-current Experiment
  - apparatus ready, sensor communications in repair
- Need to Extend CRADA to account for increased scope

